gated with affinity agents specific to the analytes. For example, when PSA was the analyte, as low as 0.1 pg of PSA was detected using SERS technology and COIN particles (FIG. **6**D).

Example 2

Optical Signal Generation and Detection: Chemiluminescence (AP)

[0202] In this example, the catalytic element is alkaline phosphatase (AP) and the substrate is Lumigen APS-5. AP acts on the substrate generating a radical intermediate which traps oxygen to form an oxetane intermediate with high energy. Breaking up of the oxetane four-membered ring generates light, which can be detected by photon counting.

Example 3

Optical Signal Generation and Detection: Chemiluiminescence (HRP)

[0203] In this example, the catalytic element is horseradish peroxidase (HRP) and the substrate is Lumigen TMA-6. In the presence of hydrogen peroxide, HRP acts on the substrate generating an oxetane intermediate with high energy. Breaking up of the oxetane four-membered ring generates light, which can be detected by photon counting.

[0204] An actual experimental example is described here for clarity.

[0205] I) Sample Prep

[0206] In an eppendorf tube, the following were mixed to make a total of 50 μL in volume: 20 μL magnetic beads coated with anti-PSA antibody (0.42% (w/v)), 10 ng (sample) or 0 ng (control) PSA, Biotinylated anti-PSA antibody, Streptavidin-HRP conjugate, and Dilution solution (1×PBS, 1% BSA and 0.05% Tween 20). The solution was incubated for 5 minutes, and was then divided into two halves for tests below

[0207] II) On-Chip Test

[0208] The specially designed chip was first covered with sticky cover for an ELISA plate. Holes were carefully punched with a fine needle in order to let out the air. About 200 μL of dilution solution was loaded to fill the channel space, while avoiding bubble formation. Some excess buffer was left outside the injection site.

[0209] 2 μL of concentrated, naked magnetic beads (carboxylated only) were loaded through the punched hole at one corner of the chip. Using a magnetic bar, the naked magnetic beads were moved through the channel to prime the pathway for transportation of the beads in the reaction mixture.

[0210] 20 μL of the above reaction mixture from above was loaded at the same site at the corner. To prevent spreading of magnetic beads, two magnets were placed in the middle of the pathway close to the injection site to trap down the beads.

[0211] The trapped beads were then carefully transported through the channels. To wash the beads more effectively, the beads were magnetically spread out a few times along the way and collected again.

[0212] At another end corner, the collected beads were carefully dispersed and 40 μL of this lightly yellow solution was taken out.

[0213] 5 μL of the above on-chip washed solution was diluted 4 times to 20 μL and 100 μL of HRP substrate mixture (50:50 Luminol:peroxide) was added to a well of a 96-well plate.

[0214] The above steps were repeated for the control sample (0 ng PSA).

[0215] The plate was then read using Clarity Chemiluminescent Plate Reader and the photon counting data were graphed with Excel.

[0216] III) In-Tube Test

[0217] 20 μL of the reaction mixture from (I) was transferred to another eppendorf tube and was spun for 2 minutes. The supernatant was removed after the tube was mounted to the magnetic separator for 2 minutes.

[0218] The bead pellet was washed twice with 100 μL of dilution solution. 40 μL of dilution solution was added to the washed beads. 5 μL of this was diluted to 20 μL and mixed with 100 μL of HRP substrate mixture (50:50 Luminol:peroxide), which was then added to a well of a 96-well plate.

[0219] The above steps were repeated for the control sample (0 ng PSA).

[0220] The plate was then read using Clarity Chemiluminescent Plate Reader and the photon counting data were graphed with Excel.

[0221] The test results are depicted in FIG. **6**D.

Example 4

Optical Signal Generation and Detection: Absorption (HRP)

[0222] In this example, the catalytic element is horseradish peroxidase (HRP) and the substrate is 3,5,3',5'-tetramethylbenzidine (TMB), with an absorption maximum of 285 nm). In the presence of hydrogen peroxide, HRP acts on the substrate generating a yellow diimine product with an absorption of 450 nm. The absorption can be detected by UV-Vis spectroscopy.

Example 5

Optical Signal Generation and Detection: Fluorescence (HRP)

[0223] In this example, the catalytic element is horseradish peroxidase (HRP) and the substrate is Amplex Red. In the presence of hydrogen peroxide, HRP acts on the substrate generating resorufin, which is excited at 530 nm-571 nm. Its fluorescence emission at 590 nm-600 nm is detected.

Example 6

Optical Signal Generation and Detection: Fluorescence (HRP & Glucose Oxidase)

[0224] This involves the combination of HRP and glucose oxidase. In this example, the catalytic element is horseradish peroxidase (HRP); the substrate is Amplex Red, and other reagents including glucose oxidase and glucose. Contrary to Example 5, the hydrogen peroxide is generated from the reaction of glucose oxidase with glucose. HRP acts on the substrate generating resorufin, which is excited at 530 nm-571 nm. Its fluorescence emission at 590 nm-600 nm is detected. Alternatively, if the catalytic element is glucose oxidase, the substrate will be glucose and other agents include HRP and Amplex Red.

[0225] The characteristics of some of the embodiments of the invention are illustrated in the Figures and examples, which are intended to be merely exemplary of the invention. This application discloses several numerical range limitations that support any range within the disclosed numerical ranges even though a precise range limitation is not stated verbatim in the specification because the embodiments of the invention could be practiced throughout the disclosed numerical ranges. Finally, the entire disclosure of the patents